DOCUMENT RESUME

ED 314 015 IR 014 073

AUTHOR Newman, Denis
TITLE Application of Intelligent Tutoring Technology to an Apparently Mechanical Task.
PUB DATE Mar 89
NOTE 19p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, CA, March 27-31, 1989).
PUB TYPE Reports - Evaluative/Feasibility (142) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Artificial Intelligence; *Cognitive Processes; *Computer Assisted Instruction; *Expert Systems; Formative Evaluation; *Instructional Design; Military Training

ABSTRACT

The increasing automation of many occupations leads to jobs that involve understanding and monitoring the operation of complex computer systems. One case is PATRIOT, an air defense surface-to-air missile system deployed by the U.S. Army. Radar information is processed and presented to the operators in highly abstract form. The system identifies aircraft as friendly or hostile based on flight patterns and radio signals. The operator watches the system make life-or-death decisions about aircraft which are well out of visual range. He or she must understand what is happening during the few minutes that a track takes to traverse the radar's area of coverage and be prepared to override the system in cases of local exceptions to the decision procedure, intelligence from other sources, or overriding commands from higher echelons. Formative evaluation research is reported on INCOFT, an intelligent instructional system developed to train soldiers to monitor the automatic identification processes used by PATRIOT. The research indicates a significant way in which attempting to teach the apparently mechanical task of matching the PATRIOT identification algorithm is not an entirely mechanical process. Students do not see the task as understanding an algorithm but rather as determining the identity of the aircraft picked up on their radar. Simple heuristics are often preferred over the effortful mental arithmetic even when very few aircraft are involved. An initial step in training is to convey the notion that there is an algorithm on which these decisions must be based. Understanding and using the algorithm requires tolerating uncertainty as information on aircraft slowly accumulates. (5 references) (GL)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
X This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Application of Intelligent Tutoring Technology to an Apparently Mechanical Task[1]

Denis Newman
BBN Systems and Technologies Corporation

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Albert Stevens
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ED314015

The increasing automation of many occupations leads to jobs that involve understanding and monitoring the operation of a complex computer systems. One case is PATRIOT, an air defense surface-to-air missle system deployed by the U.S. Army. Radar information is processed and presented to the operators in highly abstract form. The system itself will assign identities to aircraft as friendly or hostile based on flight patterns and radio signals. Sitting at a console inside a windowless control station, the operator watches the system make life-or-death decisions about aircraft which are well out of visual range. He or she must understand what is happening during the few minutes that a track takes to traverse the radar's area of coverage and be prepared to override the system in cases of local exceptions to the decsion procedure, intelligence from other sources, or overriding commands from higher echelons.

This paper reports formative research on an intelligent instructional system developed to train soldiers to monitor the automatic identification processes used by PATRIOT. Understanding an automated system appears to be a well-defined, perhaps mechanical task. The operators, who are junior-level officers, are not expected to make judgements on the basis of incomplete information and the automated system itself can be described as an arithmetic algorithm. It appears, however, that human monitoring of the massive amounts of information processed by the system is actually much more heuristic. It also turns out that understanding the fact that there is a computer system that can be understood on its own terms requires insight into the context and goals of the task.

IR014073

[1] Paper presented at the annual meetings of the American Educational Research Association, San Fransisco, March, 1989. INCOFT was sponsored by the Joint Services Manpower and Training Technology Development (JS/MTTD) Program and monitored by the Army Research Institute (ARI) under Contract MDA903-86-C-0382. The views, opinions, and findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

Monitoring automated systems provides an interesting class of occupations to which to apply intelligent instructional technology. Classically, intelligent tutoring systems are built around a model of expert knowledge which is the object of instruction as well as a model of student's partial understanding of the expert knowledge which is used to direct instruction (Brown & Sleeman, 1982; Wenger, 1986). In the case of an automated system, the expertise is actually a computer program--perhaps even an expert system. Instead of modelling the expertise of the human operator, INCOFT contains a simulation of the PATRIOT automated decision logic. This is a major simplification of the classic paradigm since it avoids all the deep issues of representation of the *human* knowledge to be transmitted. Since the weapon system has never been used in actual combat, there is no obvious pool of expertise on which to draw in any case.

INCOFT also avoids modelling the knowledge of a human instructor or the student's understanding. Instead of having the system control the instructional sequence, we draw on the extensive human resources in the context of instructor-student interaction for monitoring progress and directing next steps. Observations during formative research and during actual use of INCOFT indicate that learning and instruction in this context is far from mechanical in spite of the fact that the target domain is an algorithm. The novel application of intelligent tutoring technology affords student interactions with the machine and the instructor that leads to *human* understanding.

PATRIOT Identification of Aircraft

A PATRIOT battalion consists of a command center and several batteries each with a supply of missiles and its own engagement control station operated by two soldiers, generally an officer (Tactical Control Officer) and an enlisted soldier (Tactical Control Assistant). Each operator has his or her own console but there is a division of labor such that the assistant (TCA) is in charge of firing the missiles and system maintenance, while the officer (TCO) is in charge of "friendly protection", that is, monitoring the development of the battle and assuring that friendly aircraft are not misidentified as hostile.

PATRIOT uses a point system for classifying aircraft picked up on its radar as friendly or hostile. The airspace surrounding the battery and any assets it is defending is divided into volumes. Figure 1 shows a situation typical of scenarios used in our training. Aircraft that penetrate a defensive volume lose a certain number of points for each kind of volume they enter. Friendly aircraft presumably know the exact location of these volumes as

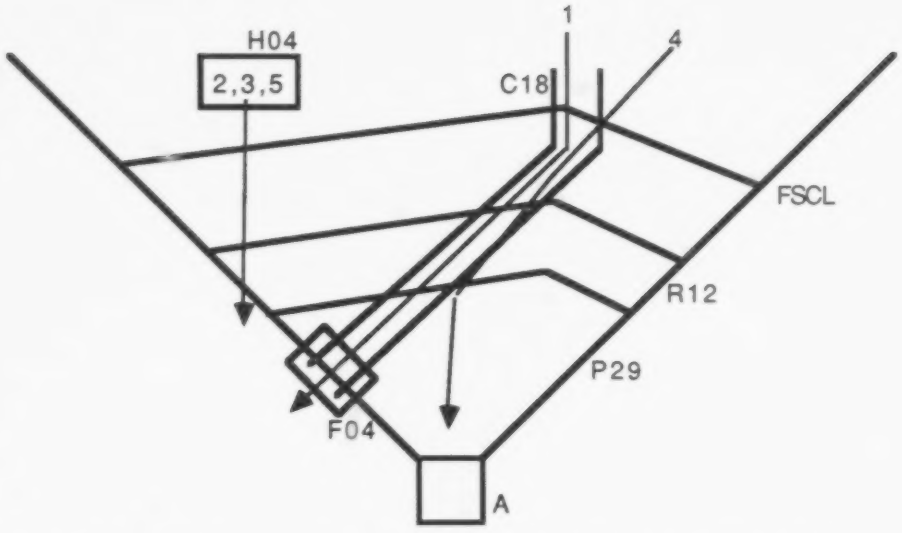

Figure 1: Schematic of PATRIOT situation display. The V-shaped area is the search sector for the battery. The line labelled FSCL is the "front line". A Restricted (R12) and Prohibited (P29) volumes are shown. FO and HO indicate locations where friendly or hostile aircraft are likely to originate. C18 indicates a safe passage corridor. "A" is an asset, in this case the PATRIOT battery. The tracks for 5 aircraft are shown.

well as of safe passage corridors which cut through them. Flying so that they are aligned with the corridor, friendly aircraft not only avoid losing points for defensive volume penetration, but actually accrue positive points as a friendly indicator. Depending on the specific tactical situation, there are also speed and altitude limits which cause points to be added or subtracted. Finally, there are codes (e.g., NATO Identification Friend Foe (IFF)) which friendly aircraft can transmit that supply additional evidence of friendly status. The sum total of the points any aircraft has accumulated allows the PATRIOT computer to assign an identity (Friend, Assumed Friend, Unknown, or Hostile) in accordance with certain predefined thresholds. Figure 2 shows the hypothetical weight set and thresholds that we used in our research.

PATRIOT can operate in automatic or manual identification mode. In automatic mode, the tracks, indicated by icons representing the possible identity states, change their identification without operator intervention. To override an identity in automatic mode or to assign an identity in manual mode, the operator must "hook" the track by moving a cursor to the icon and pressing a hook button and then press a button for the specific identity intended. In peacetime or when there are a small number of actions to be

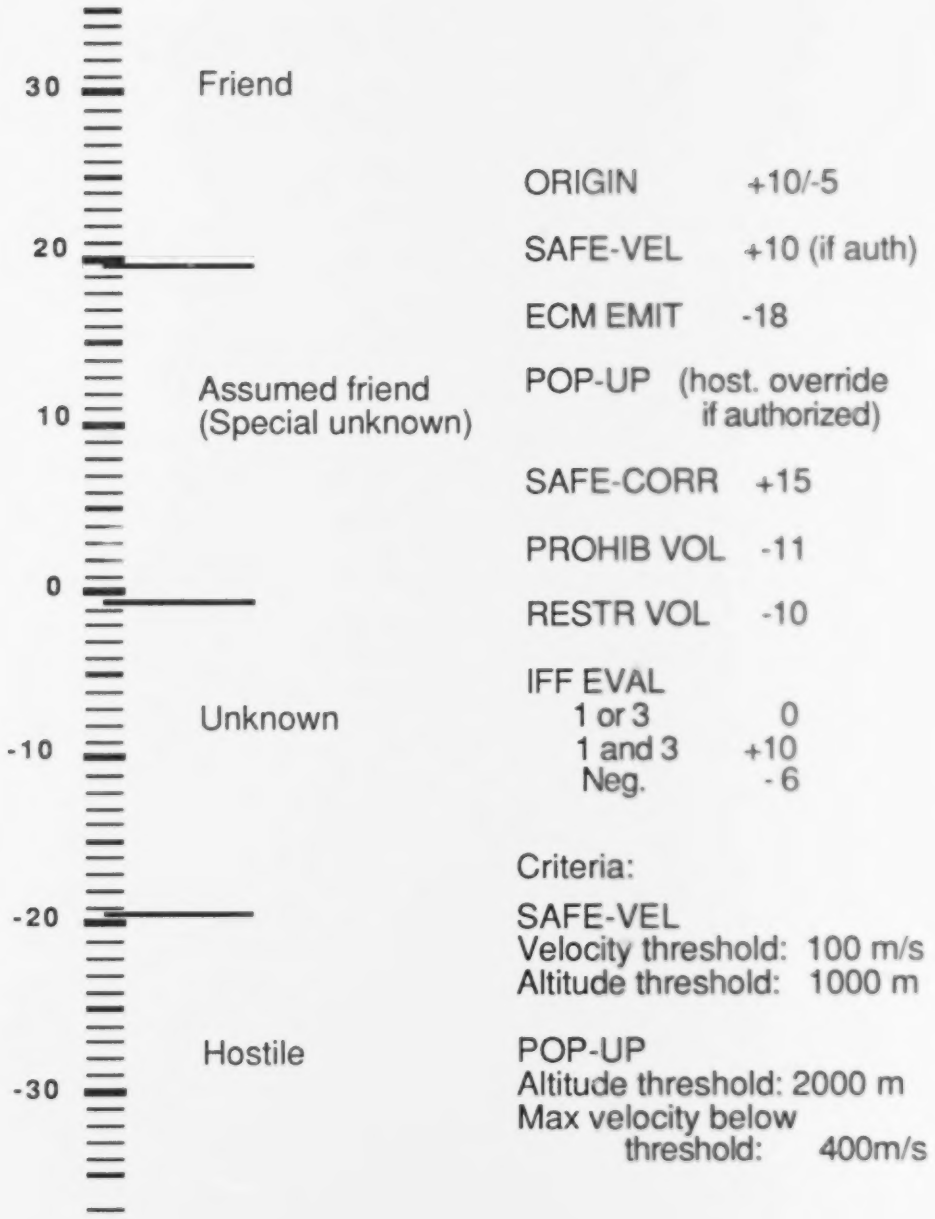

Figure 2: Hypothetical weight set and thresholds used in INCOFT research scenarios.

taken identification is done manually. Under combat conditions, PATRIOT is likely to be put in automatic mode so larger numbers of tracks can be processed.

For each track, the PATRIOT console display provides a track history in tabular form indicating what terms should be included in the sum giving the point total for the track. Figure 3 illustrates the "Track Amp. Data Tab" (Track Amplification Tabular Data Display). For example, if the aircraft is flying inside a safe passage corridor heading within a certain number of degrees of the center line, an indicator will appear next to SAFE-CORR. In automatic identification mode, this will signal that a certain number of points have been added to the aircraft's score. In manual mode, the operator has to add the points mentally. Knowing the weight set, that is, how many points to add or subtract for the various terms, and comparing the resulting score with the given thresholds, an operator can calculate an identity. Some of the terms are conceptually complex. For example, "minimum safe velocity" (SAFE-VEL) may or may not be authorized but if it is, an aircraft can *gain* points if it is flying below both altitude and speed limits (a flight characteristic not associated with an attack). It is not obvious to students that the indicator for SAFE-VEL means that points should be added (for meeting the criteria) or subtracted (for violating the criteria).

While the job of operator can be quite complex in other respects, the system identification function is defined fairly narrowly in terms of this mental arithmetic. Cases where the system-assigned ID may be incorrect are

```
              TGTNO        THRT   TLR   TLL   ENGST/M    ID/SZ/IDS     CONFLICT ID:
      -N       004                +00   +99              AF/  /OPR   RECOMMEND-ID:
                                                                          ORIGIN:
              GEOREF          ALT     SPEED    HDNG     RANGE ELEV      SAFE-VEL:
00:01:44                    1.0 KM  280 M/S   222       056 KM         ECM EMIT:
          IFF CONDITION:                                                 POP-UP:
                MODE:      4         1         2          3            SAFE-CORR:   L
                CODE:                                                  PROHIB VOL:
              RESPONSE:     NO RESP  NO RESP NOT INIT    NO RESP       RESTR VOL:
               QUALITY:                                                IFF EVAL:    N
```

Figure 3: The "Track Amp Data Tab" for track number 004 showing local (L) determination of safe corridor correlation and a negative (N) IFF evaluation

not considered in school-based training. For example, friendly aircraft returning across the front line from an attack on enemy positions may be damaged, their transponder may be damaged, they may be flying off course and so on. Such cases that may require judgment are specifically not considered on the grounds that these trainees must learn to follow a set of procedures which can be set down unambiguously. The commanders at higher levels have the responsibility for setting the criteria for firing the missiles and thus assume the risk themselves. This situation means that the identification task can be stated clearly. *The task is not to acquire the expertise of a seasoned soldier. The task is to learn the algorithm used by the computer and be able to reproduce it.*

Student Difficulties with the Identification Task

Initial research examined student understanding of the identification process after working with a conventional simulator. Students were given short (3 to 5 minute) scenarios on the INCOFT. They were interviewed beforehand on their understanding of identification principles and afterwards, following up on the feedback provided by INCOFT. Student understanding was generally poor. A majority of students did not recall the criteria the PATRIOT computer used in assigning positive or negative points for speed-based factors or corridor alignment. For example, getting points for a safe passage corridor requires that the aircraft be in the corridor *and* aligned with its centerline. Many students mistakenly believed that an aircraft simply crossing through a corridor would get points.

In addition to not understanding the criteria, many students did not even carry out the mental arithmetic. Tracks which had a positive indicator were declared friendly before sufficient points were accumulated, and tracks with a single negative indicator were declared hostile while the PATRIOT computer would have still considered them unknown according to the given point values and thresholds. Further, many students did not notice important identity changes in the middle of an aircraft's flight path. Their tendency was to find a single identity for an aircraft and leave it at that.

The following is a transcript of portions of a formative research session with two students illustrates the observed tendency to treat the task of identification as determining a single identification of the aircraft as either friendly or hostile rather, as PATRIOT does, as a process. These students had already finished the portion of the program of instruction concerned with identification. They have been given a very simple scenario involving only two aircraft. The identification of both aircraft cannot be determined on the basis of immediate information. One aircraft eventually becomes

identifiable as hostile, the other eventually becomes a friend. S2 is acting as the operator while S1 is watching and reading a sheet of paper containing the weight set. S2 starts by asking the interviewer if he can use IFF interrogation, that is, to send a radio signal that will elicit a code from the aircraft's transponder to help identify it.

S2: I do have IFF?

I: Yes, you can IFF.

S2: Response... valid mode one. [punches Friend switch]

S1: Zero points.

S2: Zero points?

S1: For a valid mode one.

S2: That's a ally isn't it?

S1: Um, so far still a ... no still an unknown. (Mumbles to herself as she adds up points.)

S2: See, on mode one he's got a valid.

S1: It says one or three is zero points. Modes one and three is plus ten points. Negative is minus six.

The aircraft's response to the interrogation was a valid mode one code but no other valid codes which would help determine its identity. S1 looks at the weight set and reads off zero points. S2 takes the valid mode one signal to be a qualitative rather than a quantitative indication: "ally" rather than 0 points. S1 restates the point value but S2 leaves the identification as Friend.

The next segment of transcript occurs during the replay of the scenario exercise. INCOFT announces that S2's identification of the first track as Hostile was incorrect--at that point it was Unknown. S2's explanation for his error was that in the weight set he had used earlier on the PCOFT (the conventional simulator) was different. But his incorrect recall of the procedure was in terms of a qualitative rather than quantitative rule.

INCOFT: You identified track 11 as a hostile aircraft. That is not correct. Track 11 is an unknown aircraft.

S1: You made him hostile?

S2: Well, the IFF is negative. I was thinking of the other point system.

I: The point system that you used in the PCOFT?

S1: Negative IFF was an automatic minus 20.

I: Minus 20?

S1: Uh...

S2: So he's hostile.

I: Oh, I see. Here it was only worth minus 6.

S1 Minus 6.

In the INCOFT weight set, an "automatic minus 20" essentially puts the aircraft into the Hostile end of the scale. The weight set he had trained with would have left the aircraft as unknown and not yet engagable.

In the next segment of transcript from the same interview, the student is asked about his friendly identification of the first aircraft.

I: You had indicated this one as a friend, do you recall what you were thinking of at that point--

S2: It had mode one, IFF.

I: Ok. And that usually means in your weight set?

S2: Mode one's ally.

I: Yeah, the thing is that different TSOPs use different, you know, weight sets and this is like a weirdo thing so it's understandable if it came up different. So normally what would you do with a mode one. That would be, uh, plus 20 points or...

S1: Usually it's one and a three. It doesn't usually come up with one or three.

I: Yeah. Ok so. Oh I see, so that would usually be an ally indication.

S2: Either that or a commercial aircraft. One of those two.

Again it is clear that the student takes the indicators to be qualitative rather than quantitative indications. It is clear from these examples that not all students approached the task this way--S1 was doing the calculations and even telling S2 the results. But in spite of these prompts, S2 continued to take a qualitative approach to the task.

The students' tendencies were understandable given the kind of practice provided by the conventional simulator. Most tracks in the conventional scenarios do not contain both positive and negative indicators, for example, correctly fly the corridor but fail to give correct NATO IFF response. They can be assigned an identity as Friend or Hostile; seldom do tracks remain Assumed Friend or Unknown. For some students, there was a very strong impression that all incoming tracks originating at a distance become hostile and all outgoing tracks are friends.

24T3: In PCOFT most come from up here and come in. Either straight come in or start at just about the middle of your scope and move out. It's one of those things where you look at it, it's almost automatic. You don't have a hard time trying to figure out who they are. After you've been in there a while, anything that pops up in the middle of your scope you know that's going eventually to be a true friend going out. Only things that change are something that comes in from out and goes down a corridor.

This was not actually true: conventional scenarios did contain ambiguous tracks with positive and negative points. However, students seldom noticed such cases and their errors were undetected. Given long scenarios with hundreds of tracks to identify, the students' task became to assign an identity as Friend or Hostile to each track as it appears. This task is in contrast to PATRIOT's identification process that assigns an identification only once sufficient evidence has accumulated and reevaluates the decision in the face of new evidence.

Our formative research indicates a significant way in which attempting to teach the apparently mechanical task of matching the PATRIOT identification algorithm is not an entirely mechanical process. Students do

not see the task as understanding an algorithm but rather as determining the identity of the aircraft picked up on their radar. Simple heuristics are often preferred over the effortful mental arithmetic even when very few aircraft are involved. In other words, an initial step in training is to get across the notion that there is an algorithm on which these decisions must be based. Understanding and using the algorithm requires tolerating uncertainty as information on aircraft slowly accumulates. Most importantly, it requires seeing all the aircraft as going through an identification process that make take many minutes as opposed to a single point determination.

Introduction of an Intelligent Instructional System

INCOFT grew out of earlier research and development projects at BBN on intelligent instructional systems. An earlier system, TRIO, also dealt with a *real-time* operational task, aircraft navigation (Ritter & Feurzeig, 1988). Like INCOFT, TRIO was built on an AI workstation, made use of several modes of presentation--expert demonstration, replay and critique-- and made use of speech synthesis for feedback as well as for simulating communication during the running of a scenario. INCOFT simulates the operator's console and presents scenarios on which the student can practice tactical operations. INCOFT consists of a stand alone console containing a Symbolics AI workstation and a DECTALK speech synthesizer which serves as the voice of a "tutor." The Symbolics monitor is mounted in the console so that it can represent the circular PATRIOT CRT and use the edges of the screen (outside the circular representation of the CRT) for feedback and additional information.

INCOFT was intended for use within an ongoing program of instruction replacing part of the conventional simulator-based instruction (Newman, Grignetti, Gross, & Massey, in press). We developed approximately three hours of courseware consisting of eight scenarios intended for use as an alternative to conventional simulator practice concerned with the duties of the TCO, that is, identification and friendly protection (Newman & Lubetsky, 1988). Our choice of domain and our design of the system and its courseware was based on formative research with students and instructors. Instructors served as subject matter experts for both the officer's job and for the instructional process at the school.

The basic instructional strategy was very similar to that used with the conventional simulator. In order to teach a student how the system performs automatic identification, scenarios are run in manual identification mode and students attempt to make the same identifications that PATRIOT would have

made. The assumption is that if an operator can mimic the PATRIOT identification algorithm, then he or she must understand the algorithm.

INCOFT provides feedback by virtue of an "expert" embedded in the system. The expert in this case is largely a simulation of the PATRIOT program which assigned identities. The student's manual identification is compared to how (and when) PATRIOT would have done it. The articulate expert also provides demonstrations of how automatic identification mode would have handled the same situation.

Commentary on Student Actions

As in a classical intelligent tutoring system, INCOFT compares the student performance to an expert performance, in this case a simulation of the PATRIOT computer. The student is presented with a scenario of between 2 and 13 minutes in which he or she must manually identify a number of tracks. A typical scenario is diagramed in Figure 1. Once the scenario begins, the students are on their own until all the tracks have made their last significant movement. The scenario is then replayed and each operator action is compared to the expert action and reviewed, relying heavily on synthetic speech and ostensive actions such as highlighting the track icon. This replay runs much faster than real time up to the point where an identification action had been taken. At that point, the replay pauses and a threshold indicator similar to that in Figure 2 is displayed on the screen next to the situation display along with the calculation that PATRIOT would have made. The synthesized voice of the tutor notes the student identification action and points out its own calculation as shown on the threshold indicator. When possible, the tutor points out sources of error that are logically consistent with the student's actions.

Summary of ID Actions Table

After the replay, a table is presented summarizing all the tracks and indicating what the expert would have done compared with what the student did. Figure 4 illustrates the table entry for one track. Summary "scores" for correct ID and time to ID are presented at the bottom of the table. The feedback provided by the table organizes and integrates the feedback provided by the preceding replay. It is a very useful summary for both students and instructors. First, it groups actions by track so that all the actions that were taken or should have been taken for that track can be considered as a unit. Second, it lists all the actions that PATRIOT would have taken and matches up the student action and non-action (e.g., interim identifications that the student neglected). Third, it gives the lag time between the point that PATRIOT would have changed a track's identification and when the student did. It is always expected that the student will lag

Track	EDWA Time	ID	Your ID	Your ID (secs)	URGENCY TLR	TLL	ATC	# of Tracks
004#	01:10	U	same	—	+05	+99	1	5
	01:39	AF	same	10	+00	+99	1	5
	02:00	U	AF	—	+00	+99	1	5
	02:29	H	same	65	+00	+87	1	1
	Average		75%	37				

Figure 4: One entry on the Summary of ID Actions table showing that the student made three of the four identifications same as PATRIOT decision logic ("EDWA") but took 65 seconds to make the critical hostile (H) identification

behind the computer, but a long delay can indicate that the student did not notice the relevant event (e.g., the track's crossing into a volume or leaving a safe passage corridor). Fourth, the table relates the identification actions to other aspects of the situation which affect the urgency of the identification action and ought to be considered in relation to the lag time.

Expert demonstrations

The summary table serves as a menu for selecting demonstrations of specific tracks in addition to providing detailed performance data. The student can choose an "expert demonstration" for any track on which he or she made an error, late identification, or for which he or she did not understand the identification process. For example, interim identifications, e.g., where a track is reclassified twice before obtaining a final identification, are often not noticed by the student. For identifications that are done correctly, the lag time may have been much greater than the student thought due to factors that were not noticed. The demo replays the scenario in "fast forward", focussing on the track that the student requested. The selected track is highlighted and the replay pauses each time the track reaches or is about to reach a spot where the point total will change. The tutor (synthesized speech) points to the cause (volume penetration, corridor dealignment, speed or altitude change, etc.) by highlighting it and explains the specific cause and how the total points are affected. The threshold indicator displays the increase or decrease in points. In cases involving specific criteria, the tutor explains the criteria. For example, the points for

minimum safe velocity can be lost if the aircraft goes too high or if it speeds up. In this case, the specific violated criterion is ostensively displayed on the screen and an appropriate comment is produced by the speech synthesizer.

This expert demonstration presents the identification task from the perspective of a single track rather than from the perspective of an expert operator dealing with a large number of tracks simultaneously. This change in point of view allowed attention to focus on the identification process that PATRIOT is going through *simultaneously* for each of many aircraft at a rate that would be impossible for a human operator.

Instructional Interactions Among Students, Instructors and INCOFT

INCOFT's application of intelligent technology makes it possible to present scenarios which contain cases more subtle than those currently presented with the conventional simulator. For example, an INCOFT scenario presents an aircraft that does not give off the correct NATO IFF code but nevertheless aligns with the corridor for a minute. This particular aircraft (track 4 in figure 1) starts out as an Unknown, changes momentarily to Assumed Friend when it aligns with the corridor but goes back to Unknown when it dealigns but is still within the corridor. While still within the volume of the corridor, it becomes hostile as it correlates with the Prohibited Volume. The student may identify the track correctly as Hostile once it leaves the corridor but this is after a critical minute has already elapsed. Cases such as these give both the intelligent instructional system and the human instructor rich examples about which to provide commentary on the student actions.

Intelligent Demonstration of Process

A powerful pedagogical function of INCOFT's expert system was revealed in the students' responses to the single track expert demos of the identification process. Students had never been able to focus on a single track. Being able to do "longitudinal" studies of tracks was very useful to them. Many students remarked on being able to see the precise point at which, for example, a track dealigned with a corridor and was declared hostile. The "articulate expert" applied to a single track focussed the student's attention on the process by which PATRIOT calculates an identity.

The following transcribed comment occurred at the end of an expert demonstration of a track that he had identified as Hostile within 9 seconds. This student had experience in other air defense systems and was being

retrained for PATRIOT. He thought that they had seen it turn and speed up but in the demonstration he was surprised to realized that he had noticed it only on the second turn.

S3: The only thing about the replay that I see is it shows you exactly the flight pattern he used to come in. And like I say it's just giving you another picture of where you missed making a change in his ID on that one track. I can see where it would be very useful in a lot of instances where you've got a lot of busy traffic and you missed it. You know, well, why did you miss it. And once you know why you missed it, you train your mind, of course, and your eyes to coordinate that. You're going to be looking over at the side of the scope and as soon as you see his swing on a target like that, your eyes just go over there quickly to see if anything has changed, if his LNIP[2] has changed or anything, his velocity, and you can tell if that things spurts out even a quarter of an inch. He's out another quarter of an inch we've better ID him again because it looks like his velocity has changed besides his direction. Yes, I think it would be able to train somebody a lot easier by being able to go back through and see where you missed it.

INCOFT's decomposition of scenarios into separate tracks in the expert demos helped to make clear the function of the PATRIOT computer and the perceptual skill of the experienced TCO. While assigning an identification to any single track is just a matter of straightforward adding and subtracting, PATRIOT is able to do that for hundreds of tracks simultaneously. A novice operator faced with, for example, 15 tracks, will have to look at each in some sequence and make identifications. This snap-shot approach makes it hard to take into consideration the past trajectory of each track, yet it is the track's intentions as inferred from patterns of motion which are the real issue. Interestingly, interviews with experienced air defense operators who were being reassigned from different systems indicated that it is the perception of these patterns for particular tracks that seems to mark expertise in air defense operation.

Instructors Putting the Process in Context

The role of the instructor in the practical exercises will also change. INCOFT was not designed to replace the instructors; instead, it changes the kind of work they do. In our test of the system in actual instruction, we found that instructors helped students interpret the data table and suggested

---

[2]Launch New Intercept Point: the point at which a missile will hit the target if launched now. This is represented as a line emanating from the target icon.

tracks that they should review. Rather than giving students their own feedback on errors, instructors discussed the feedback that the system was giving to the students using it as a basis for instruction. INCOFT freed the instructors from having to attend to the correctness of the students' actions, allowing them to focus on more subtle aspects of performance.

The following examples are taken from a session in which INCOFT was being used in instruction with students who were learning the task for the first time. The instructor is a highly experienced teacher but working with INCOFT for the first time. In this segment, the student has finished a relatively complex scenario and is looking at the Summary of ID Actions table.

S: What's the 84 mean? [referring to the summary score at the bottom of the table]

T: That's your average time, average time that you did things, 84 seconds. A minute and a half almost.

S: And it should have all been done in 30 seconds?

T: Well, remember now, 30 seconds is operator override time, and that's maximum operator override time and what we're saying there is that you have that little time to make a decision on critical things that need to be done. If you've got a target, that is if you'd put into- which tab do you have override time?

S: Uh, tab, I got it wrote down in my notes.

T: Tab zero one. And what ever you have down in your operator override time that's the amount of time you have to do something before the system automatically engages the target. Now what this says, what this says to me is that you definitely need to improve and work on your decision making ability and capability, cause 84 seconds average time in order to make a decision is a long time. If you get an aircraft going 800 meters a second,

S: Uh huh.

T: he can go a loong way in a minute and a half, a long way.

S: Okay, I want to try this one again.

This is a complex interaction in which the student displayed a misconception about a 30 second time limit introduced in another context and the instructor used the student question as an occassion to review the concept and the location in the database of the relevant parameter. The instructor returned to the initial topic and presented a graphic case for the need for the student to act more quickly. INCOFT provides the student and instructor with detailed feedback on which to base this interaction but it is the instructor, not the machine, who handles the more complex misconceptions and places the task in a motivational context.

In the next segment of transcript from the same session, the instructor is explaining a summary table presented at the end of an expert demonstration.

S: Okay.

T: All right? Uh, okay, so, it wasn't authorized so you got nothing. So your points was still zero six.

S: That's a zero, or 86?

T: That's negative, uh zero, that's a zero. Okay, you went through a resicked, restricted volume which gave it a negative ten points, so it wound up with a total of negative sixteen points, how many is, what's negative sixteen here.

S: An unknown.

T: It would still be an unknown target. That's what that means. (pause) okay.

S: So we can just allow an unknown target to come straight to

T: Well,

S: t'fly right over our heads, the radar, fly right over the radar?

T: (chuckles) well for this purpose, yes, that's why, all it's doing is looking at whether or not you identified the aircraft, not whether you protect the asset. okay.

S: Okay, okay I guess somewhere I missed the main point.

T: Okay, spacebar.

In this case the instructor is emphasizing the abstract nature of the identification task. While the student voices a real world concern, the instructor explains that the lesson in this case is about the identification algorithm not about more general issues. (In the particular scenario, a "weapons free" area would have protected the battery from unknown aircraft, but that is an engagement function not part of identification.) The instructor is thus helping INCOFT to reflect the central lesson that PATRIOT's automatic identification process will apply "mechanically" to aircraft given the system initializations. Moving a students from a qualitative view of the task to a knowledge and understanding of the automated decision logic is not, itself, a mechnical task.

Conclusions for the Use of Intelligent Technology

This field test of INCOFT in actual instruction--supervised by instructors rather than researchers--has begun to demonstrate the reasonableness of putting intelligent computational power at the disposal of instructors and the students rather than attempting to build the entire presentation into an automatic tutor. This simplification of the classic Intelligent tutoring system model is proving effective and usable in instruction. Rather than puzzling over how to get an intelligent system to decide how much feedback to provide and what kind of scenario to present next, these decisions are handed over to the people involved.

From the point of view of research in artificial intelligence, INCOFT does not represent a scientific advance. From the point of view of instructional design, however, what INCOFT doesn't do is what's interesting. Educational applications which involve automated systems or other well-defined procedures can benefit from our findings about how to use AI technology to model relatively mechanical processes with no pretense to modelling actual human cognition. By putting various decompositions or representations of the processes in the hands of students and teachers, we might expect useful instructional interactions to ensue. In fact, the resulting instruction went beyond learning the PATRIOT decision logic. The opportunity to interact with conceptually complex cases and to see, in comparison, how the PATRIOT computer would have "perceived" and handled them, leads to a different way of approaching the task involving a greater sensitivity to critical changes in the track that can clarify the aircraft's intentions.

References

Newman, D., Grignetti, M., Gross, M., and Massey, L. D. (in press). Intelligent Conduct of Fire Trainer: Intelligent Technology Applied to Simulator-based Training. Machine Mediated Learning.

Newman, D., & Lubetsky, B. L. (1988). *Instructors' guide to INCOFT courseware.* Report No. 6885. BBN Systems and Technologies Corporation.

Ritter, F., & Feurzeig, W. (1988). Teaching real-time tactical thinking. In J. Psotka, L. D. Massey, & S. A. Mutter (Eds.), *Intelligent tutoring systems: lessons learned.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Sleeman, D., & Brown, J. S. (Eds.), (1982). *Intelligent tutoring systems.* New York: Academic Press.

Wenger, E. (1987). *Artificial Intelligence and Tutoring systems: Computational and Cognitive approaches to the communication of knowledge.* Los Altos, CA: Morgan Kaufmann Publishers, Inc.